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Simulation study of the MCP-PMT in high magnetic fields

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OUTLINE

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- Magnetic field effects on the photoelectrons between the photocathode and the MCP
- Magnetic field effects on the MCP
- Magnetic field effects on the ALD-MCP

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Electron paths in the MCP-PMT

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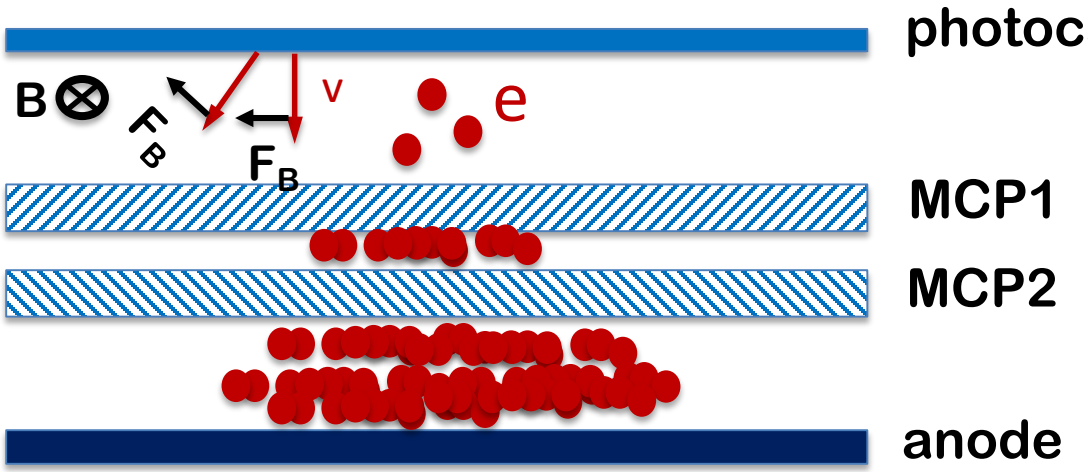

PC to the MCP1:
＞2mm
＜500V
E＜250V/mm

MCP1:
0.4mm-0.6mm
800V -1000V
E＞2000V/mm

Magnetic fields effects on Photoelectrons from the PC to the MCP1

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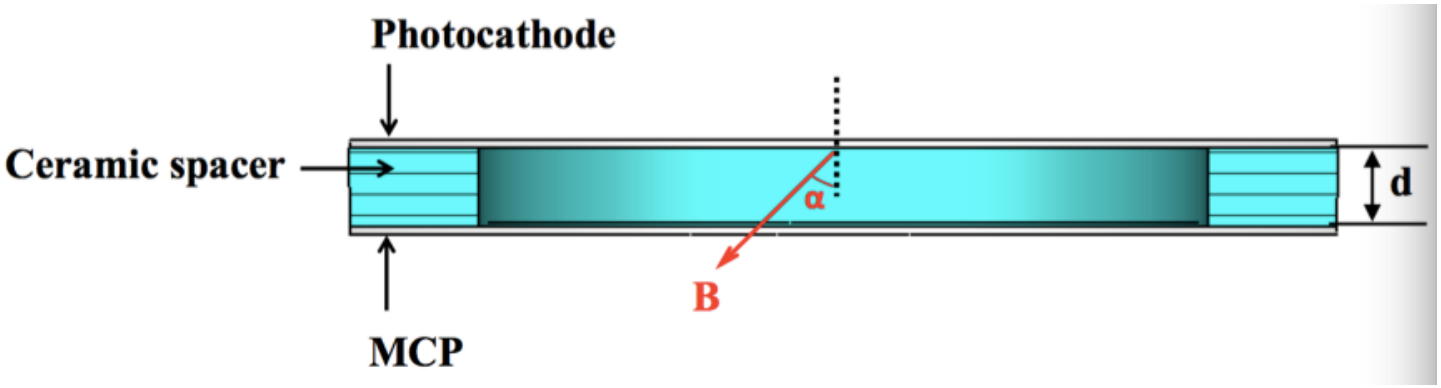
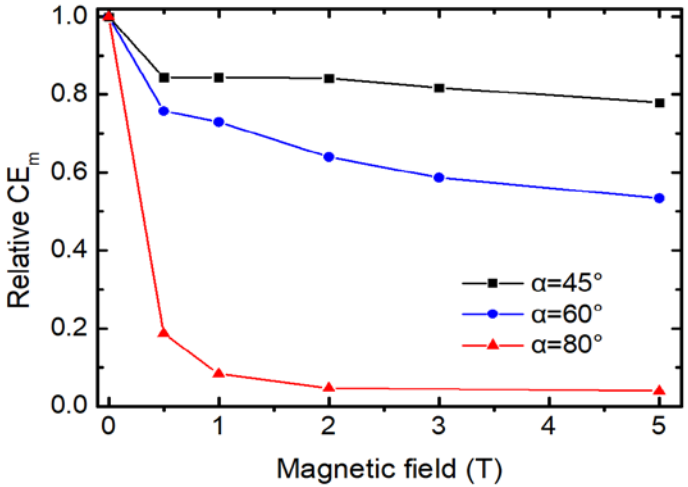
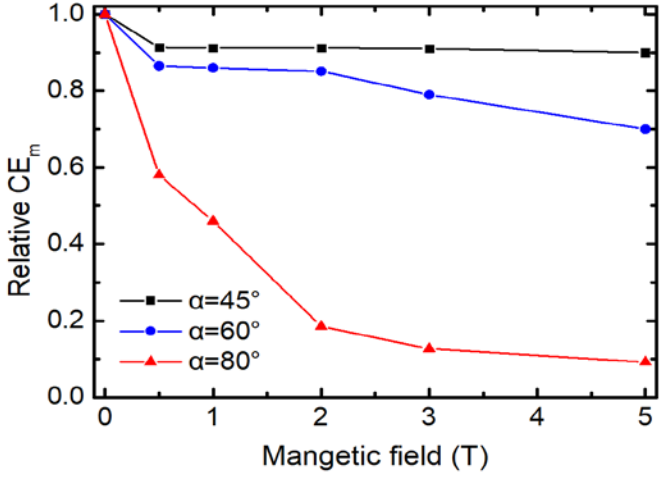


Model to simulate the magnetic fields effects on the photoelectrons from the PC to the MCP1

CE_m is the probability of photoelectrons hitting MCP
U is the electric potential between photocathode and MCP



Relative CEm as a function of magnetic field @ d=2 mm and U=500 V.



Relative CEm as a function of magnetic field @ d=1 mm and U=500 V.

Magnetic fields effects on Photoelectrons from the PC to the MCP1

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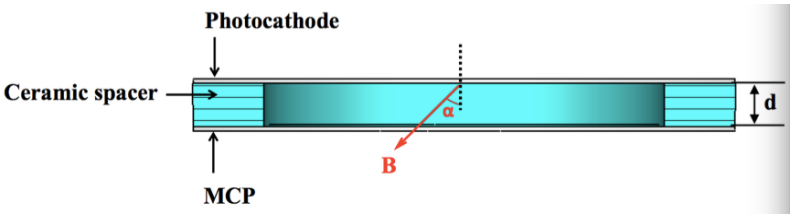
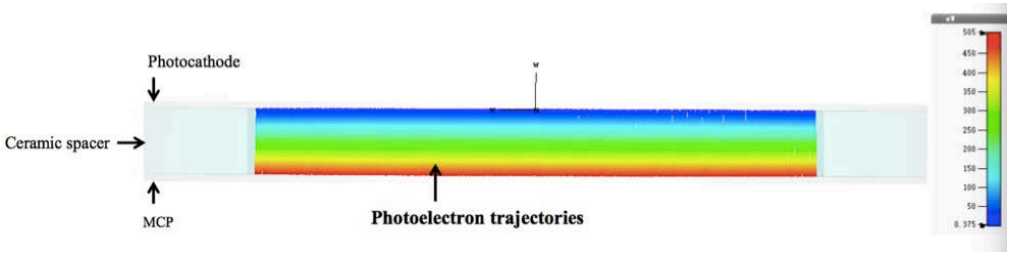
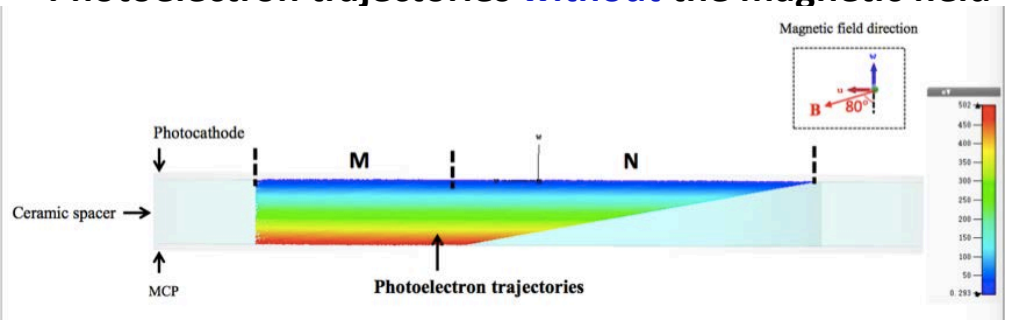


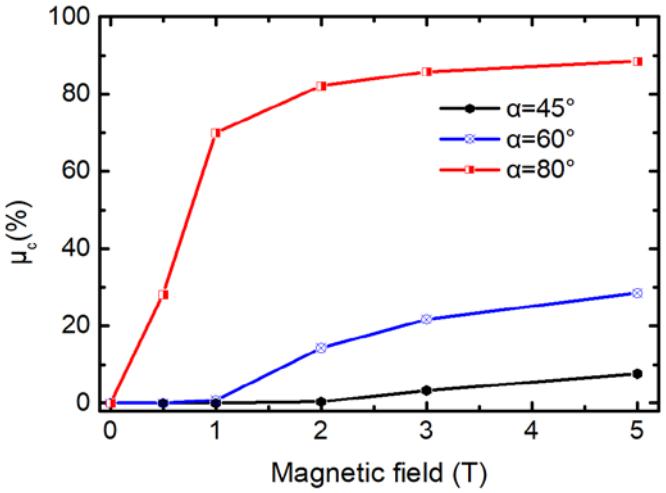
Model to simulate the magnetic fields effects on the photoelectrons from the PC to the MCP1



Photoelectron trajectories without the magnetic field



Photoelectron trajectories in the magnetic field



Please note that because of the magnetic field effects, the angle of incidence of photoelectrons strike the MCP increases with respect to the MCP normal direction.

Probability of photoelectrons striking photocathode as a function of magnetic field @ d=2 mm and U=500 V.

Nuclear Instruments and Methods in Physics Resaerch, A 936(2019)580-582

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- Magnetic field effects on the ALD-MCP

Magnetic fields effects on spiral radius of electrons in the MCP

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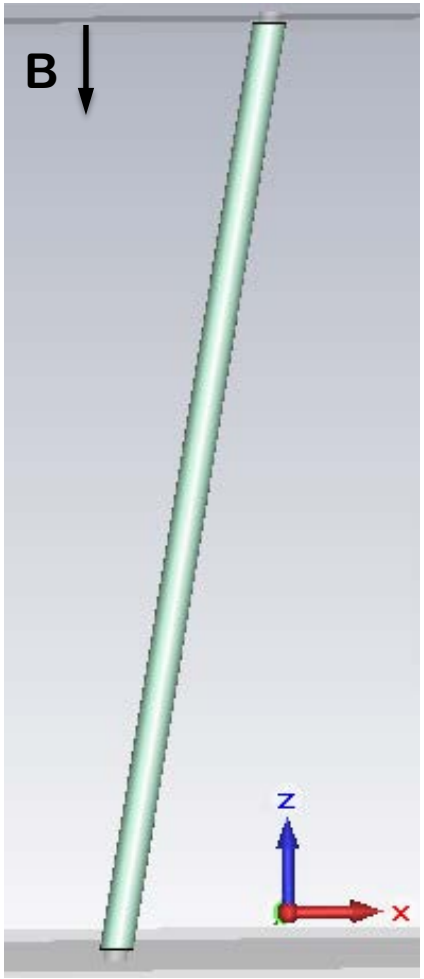


Model to simulate the magnetic fields effects on electrons in the MCP1

The force of electrons in an electromagnetic field:

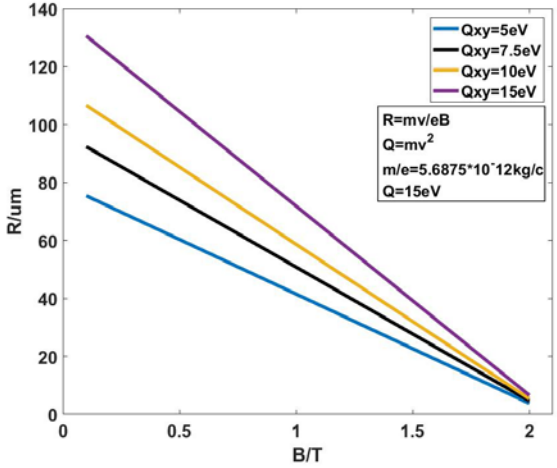
$$\vec{F} = e(\vec{E} + \vec{v} \times \vec{B})$$

In the simulation, $\vec{E} = E_0\overrightarrow{e_z}$, $\vec{B} = B_0\overrightarrow{e_z}$; hence

$$\vec{F} = B_0 v_y \overrightarrow{e_x} - B_0 v_x \overrightarrow{e_y} + eE_0\overrightarrow{e_z}$$

The effect of the magnetic field on electrons is reflected in

$$\Delta\vec{F} = B_0 v_y \overrightarrow{e_x} - B_0 v_x \overrightarrow{e_y}$$



Magnetic fields effects on the spiral radius of electrons

Assume the electron energy is 15eV, the radius of spin of the electron less than 10μm when magnetic field is 2T.

Magnetic fields effects on collision position of electrons in the MCP

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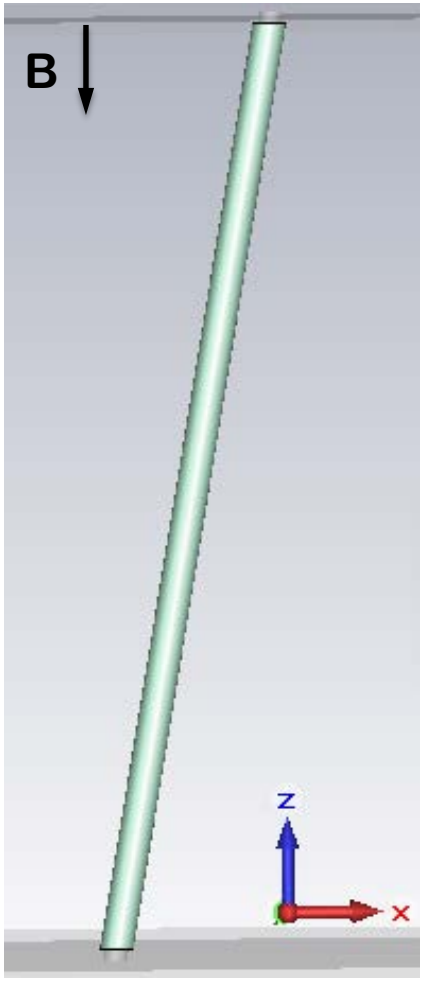
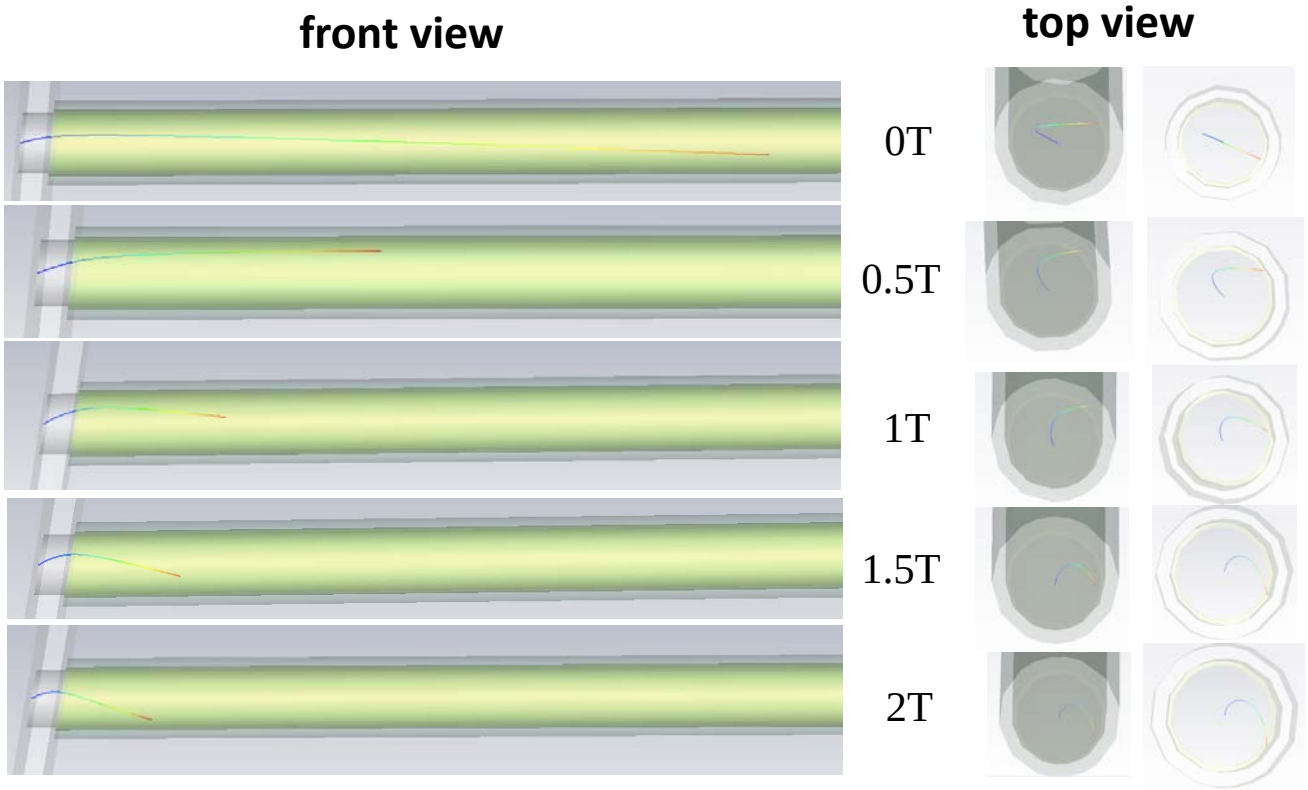


Model to simulate the magnetic fields effects on electrons in the MCP1

Electron trajectories in the MCP channel



Magnetic fields effects on collision position and collision energy of electrons in the MCP

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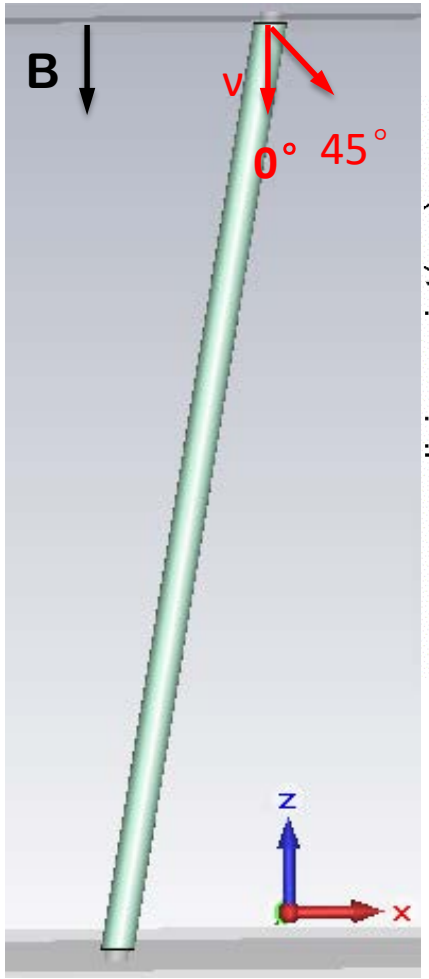
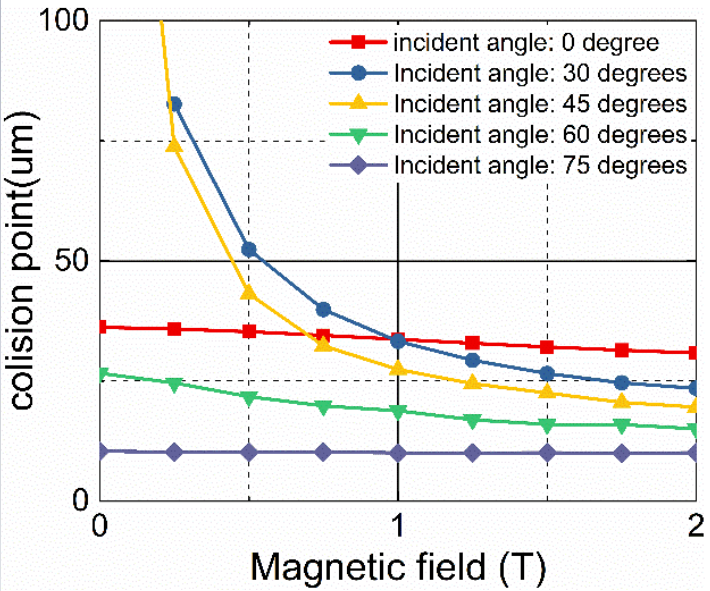
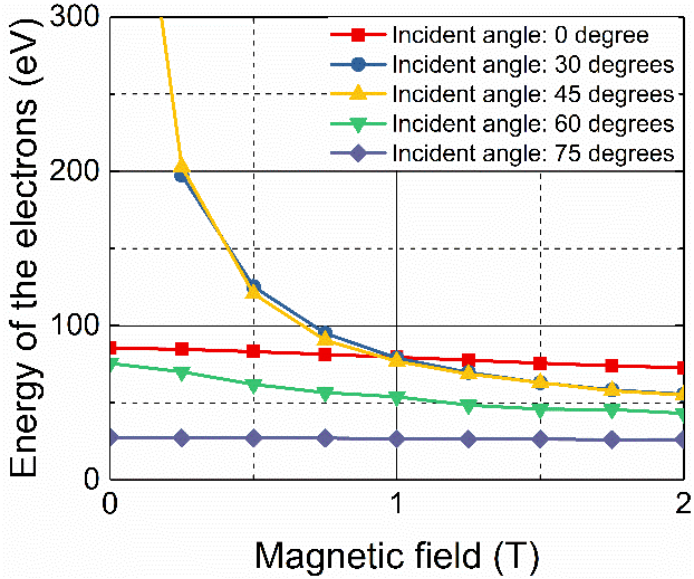


Model to simulate the magnetic fields effects on electrons in the MCP1





Magnetic fields effects on the position of the collision point (left) and the collision energy(right) for electrons with different angle of incidence

Note that because of the magnetic field effects, the angle of incidence of photoelectrons strike the MCP increases with respect to the MCP normal direction.

Magnetic fields effects on number of electrons and collision times in the MCP

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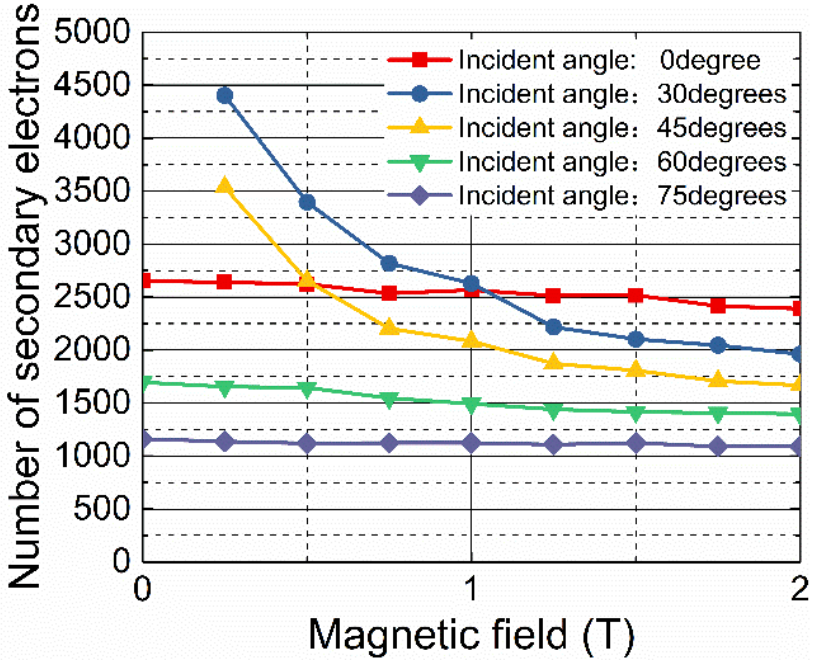

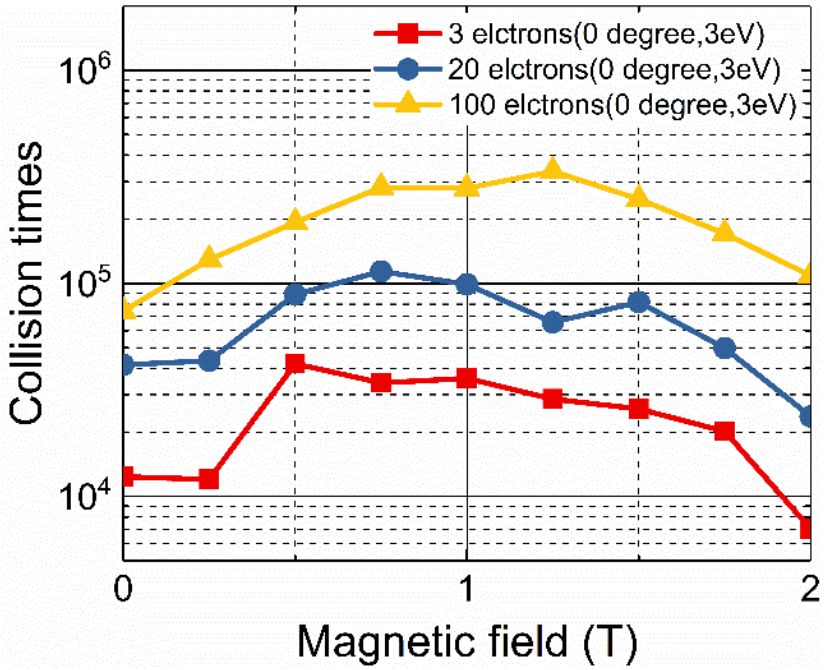

Magnetic fields effects on the number of emitted secondary electrons at the first strike with 1000 primary electrons (left) and the total collision times in the MCP (right)

Magnetic fields effects on the gain, TTS and energy of secondary electrons in the MCP

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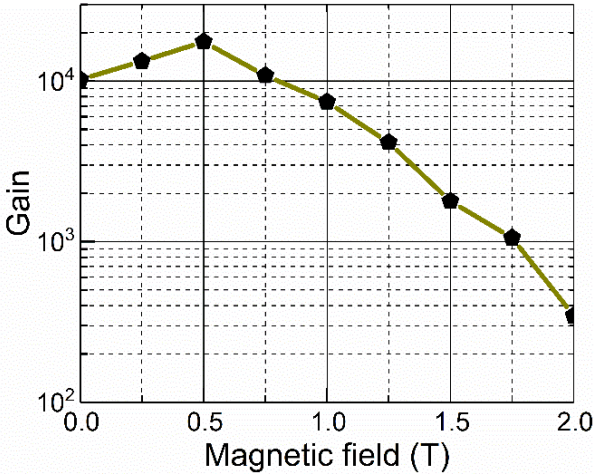

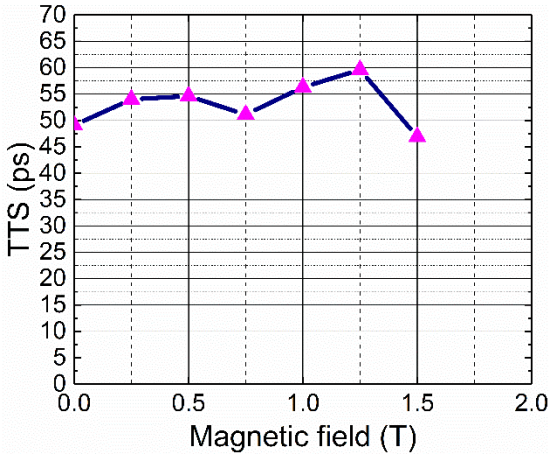

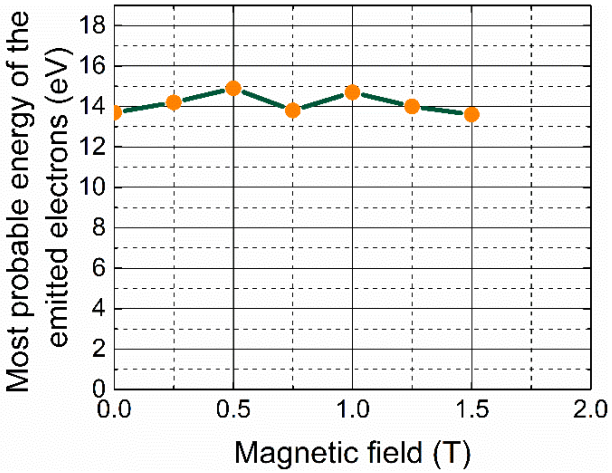

Magnetic fields effects on the Gain (left), TTS (middle) and the energy of the emitted secondary electrons (right)

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Magnetic fields effects on electrons in the ALD-MCP

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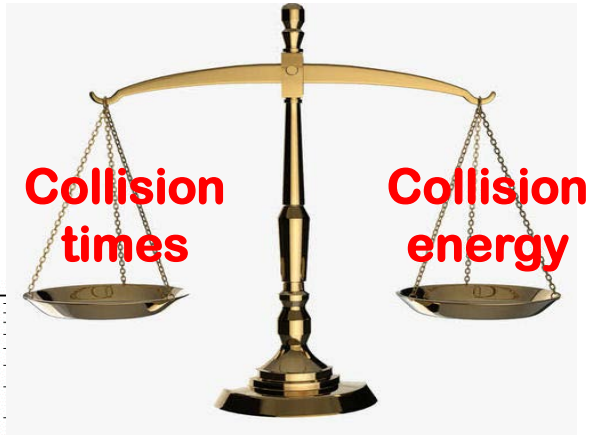
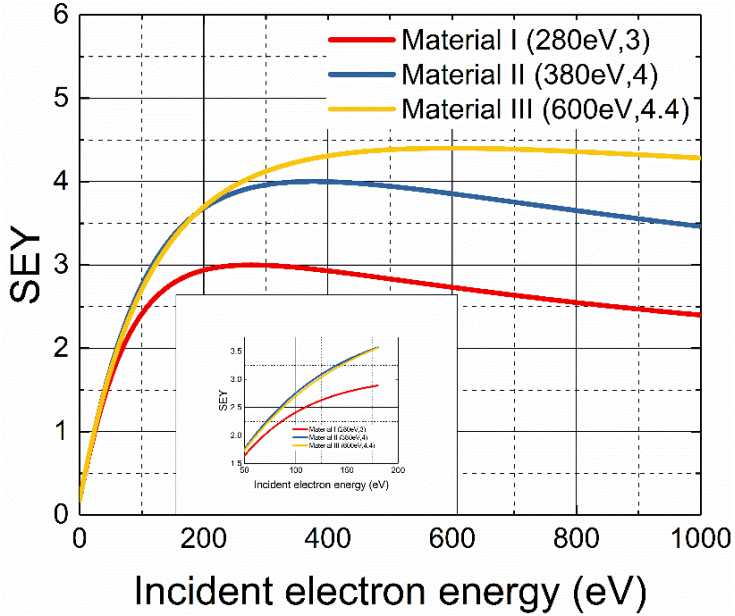
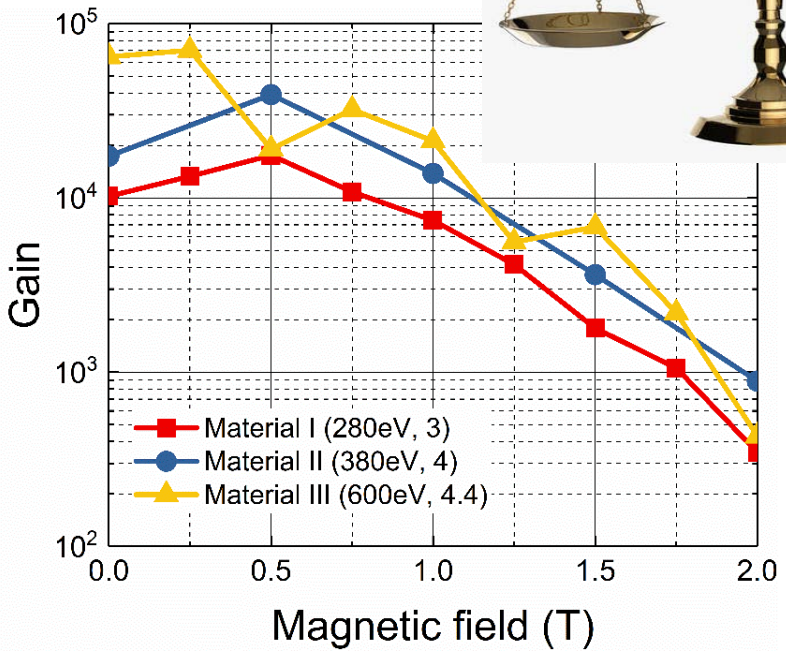
Gain





MCP of different SEY properties



Magnetic fields effects on the gain for MCP of different SEY properties

High-CE MCP and photoelectron backscattering

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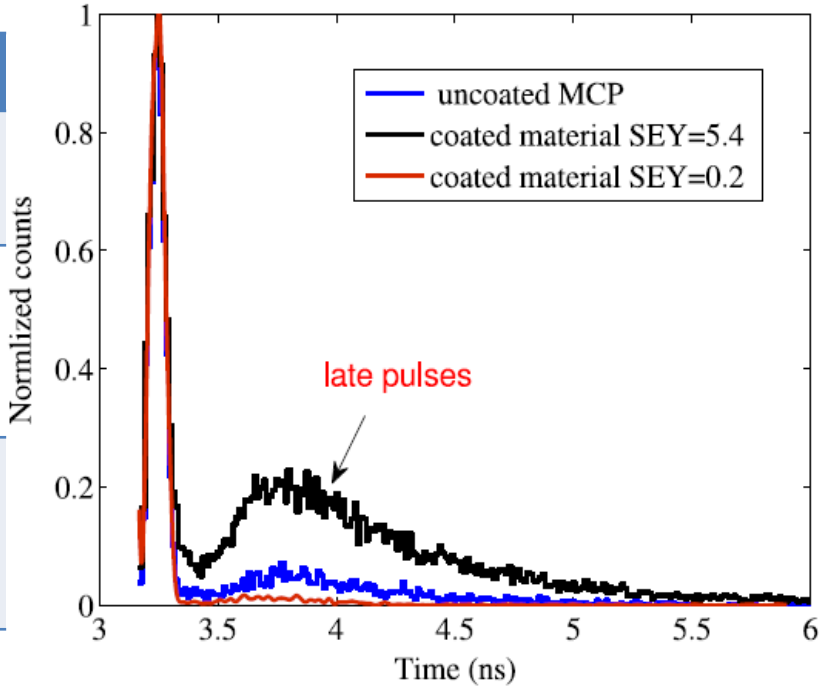
Collection efficiency of MCP coated with different materials

	CE_m	CE_l	CE
Conventional MCP δ(SEY)max=1	**55%**	**11.5%**	**66.5%**
MCP coated with a material δ(SEY)max=0.2	**55%**	**2.8%**	**57.8%**
MCP coated with a material δ(SEY)max=5.4	**55%**	**43.8%**	**98.8%**

Note: CE_m- CE contributed by the main pulses.
CE_l - CE contributed by the late pulses.

Time distribution of MCP coated with different materials



Nuclear Instruments and Methods in Physics Resaerch, A 912(2018)112-114

High-CE MCP and photoelectron backscattering

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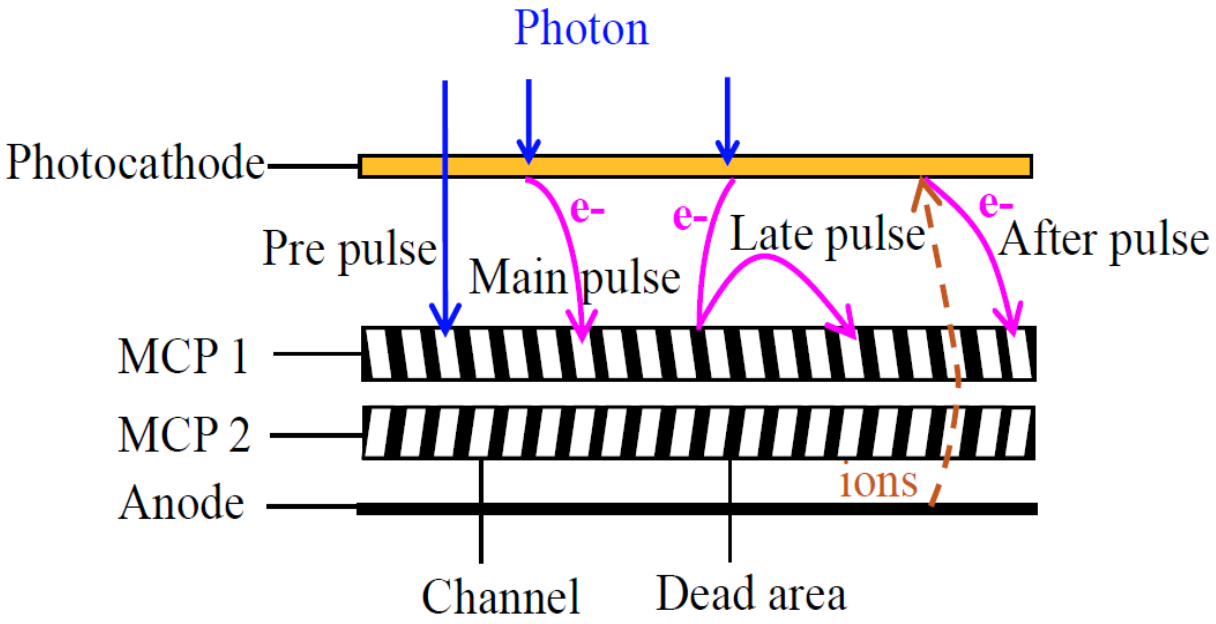
Physical processes that lead to an output pulse of the MCP-PMT



High-CE MCP and photoelectron backscattering

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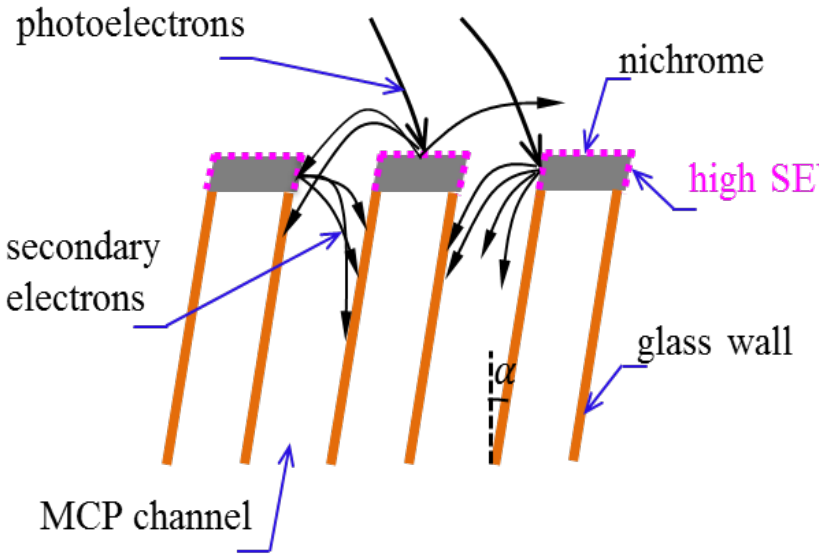
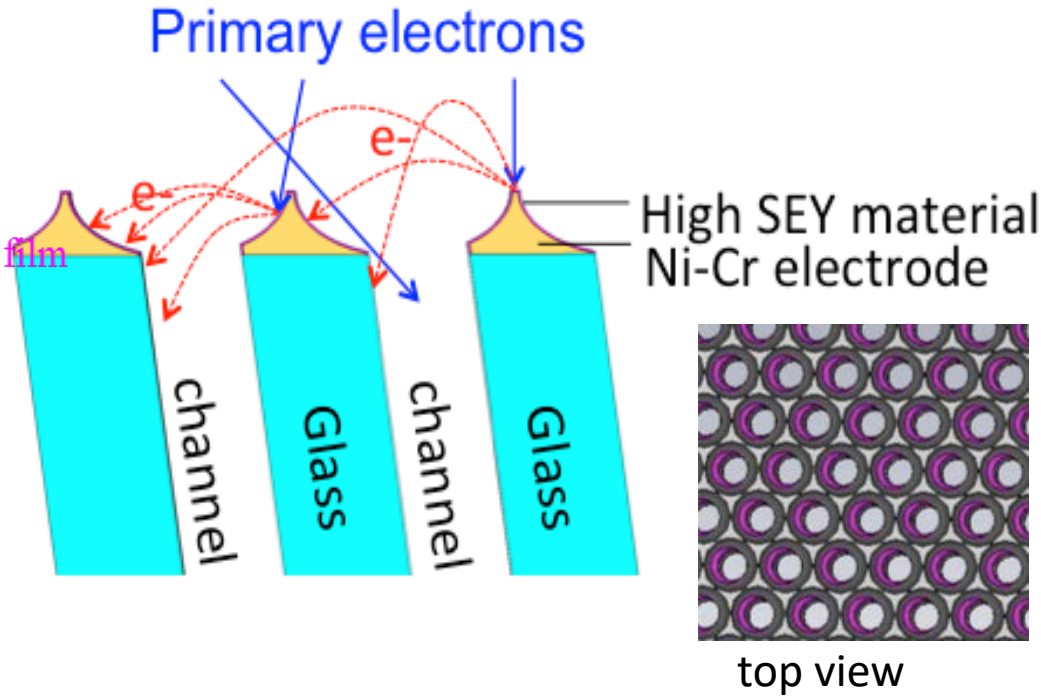
High-CE MCP



Bowl-shaped MCP



Temporal performance of the high-CE MCP and the bowl-shaped MCP

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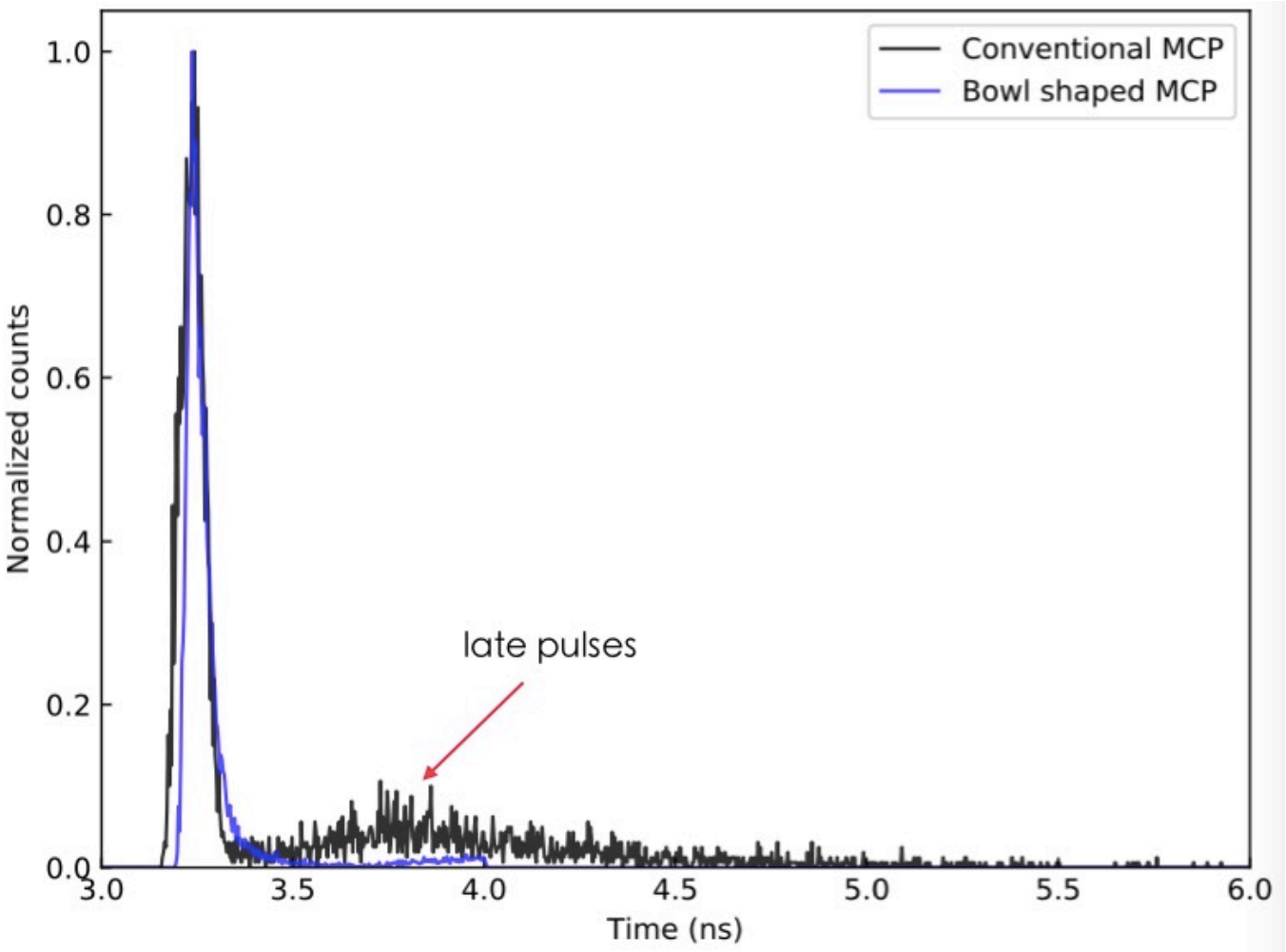

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Thank you for your attention!